Cereal stubble and trap crops in Heliothis management

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General Introduction

Helioithis management in the Australian cotton industry in the past has been heavily reliant on insecticide application. Resistance monitoring over the past several years all over the cotton belt indicates that this management approach based on chemical insecticides is no longer environmentally or economically viable. Alternative management tools being studied as part of a move towards area-wide management of this pest include cereal-cotton rotation and trap crops. Below are synopses of the progress to date on each of these management tools in the Emerald irrigation area.

Cereal Rotations and Heliothis Management

Introduction

In June 1997 a Cotton Research and Development Corporation (CRDC) funded project was initiated in the Emerald Irrigation Area (EIA), for the development of management strategies to minimise off-site movement of pollutants (sediment, nutrient and pesticides) at the paddock or farm scale (Waters *et al;* 1998). In particular, the goal was to apply plot scale research findings at the paddock scale and to assess the practicality and feasibility of adoption of these management practice by farmers. Planting cotton into standing wheat stubble was one management option which proved to be highly effective at reducing pollutant movement. A further unexpected finding was an early season reduction in insecticide sprays on cotton that was planted into the standing wheat stubble. This finding has generated interest from growers and researchers because of the need for environmentally friendly pest management measures in this area which is characterised by high levels of insecticide resistance in pest populations.

Over the past two seasons there has been an increase in the number of growers planting cotton into standing wheat stubble in the EIA. Growers have been enthusiastic to assess the potential for the rotation to reduce reliance on chemical sprays and also to reduce off-site movement of pollutants in runoff. The wheat cotton rotation (W-C) has resulted in a reduction of up to three early season sprays in 1997/98 on several farms in the district in what was regarded as a high pest pressure season. The 1999/2000 season was a low pressure season and heliothis numbers in the wheat cotton crops were not significantly different to conventional cotton crops in the EIA. Whilst a W-C has proven to be highly effective in reducing pollutant movement in runoff, further monitoring needs to be carried out over a number of seasons to assess the full effectiveness of the W-C as a means of reducing reliance on chemical applications.

This paper will outlines the development of W-C in the EIA and its potential use as a tool for heliothis management.

The development of Wheat/Cotton Rotation

In 1996/97, the first known crop of cotton was double cropped into wheat stubble (W-C) on one farm in the EIA. At the completion of the 1996/97 season it was observed that there was a reduction in the required number of endosulfan sprays applied to the W-C crop compared to the adjacent conventional cotton crop (C-C). In 1997/98 the same grower agreed to repeat the rotation with the main focus of the trial to measure runoff and water quality (Waters *et al.*, 1998) . In addition, insect and predator numbers were monitored to look at the reduced spray phenomena in more detail. Again, three less endosulfan sprays were required for the W-C crop in what was regarded as a high pressure season.

By 1999/2000 the interest in W-C rotations had increased in popularity with eight growers participating. The reason for the increased adoption of the practice by growers was two fold :

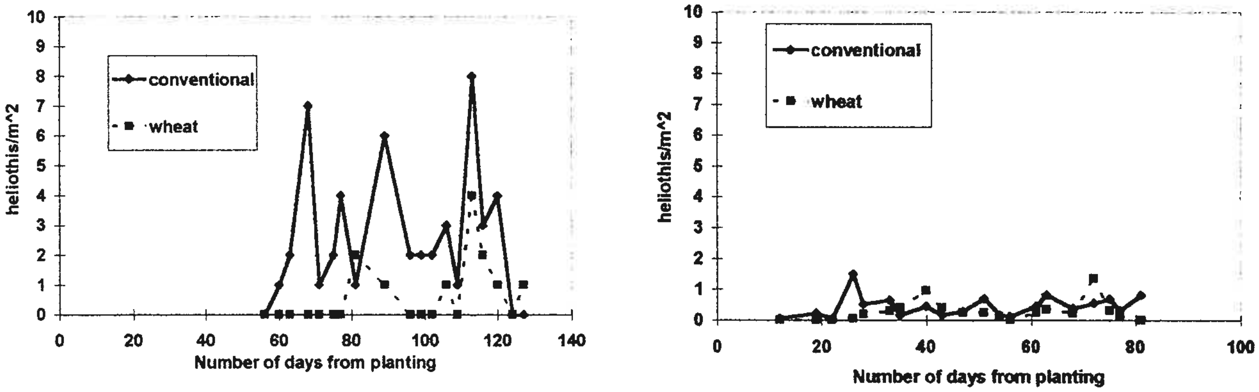
1. Previous data showed erosion and chemical movement transported off-site in runoff was reduced by as much as 70%.

2. Growers believed that W-C rotation could provide an alternative management strategy which would reduce the need for chemical applications .

Four of the eight farms planting cotton into wheat were selected within the EIA and heliothis egg, larvae and predator numbers were monitored by visual estimates and by suction sampling on a regular basis, early in the season (November to January).

Results and Discussion

The 1996/97 season had high early season pressure with average heliothis numbers four times higher than the 1999/2000 season (figure 1A and B). In 1996/97 C-C crops exhibited consistently higher heliothis numbers throughout the first half of the season in comparison to W-C crop. In contrast the 1999/2000 season was a relatively low pressure season and there was no significant difference in heliothis numbers between C-C and W-C on the four farms monitored. This was also reflected in a similar number of insecticide applications being applied for W-C and C-C over the season.



(A) (B)

Figure 1 : Heliothis larvae/m2 for conventional cotton (C-C) and wheat cotton rotation (W-C) for a high pressure season (A) - (1996/97) and low pressure season (B) - (1999/2000).

In 1996/97 it was reported that cumulative predator numbers were found to be 20% higher for the W-C than C-C (Waters *et al*; 1998). In 1999/2000 however, total predator numbers were much lower in the EIA and no significant difference in predator numbers was found between C-C and W-C.

Whilst limited, the existing data suggest, that in a high pressure season, W-C may reduce heliothis numbers and therefore chemical applications. The 1999/2000 data highlights the need for further monitoring to cover a range of seasonal conditions before the W-C system can be integrated into an area wide pest management strategy.

One possible explanation for the reduction in heliothis pressure is that the wheat stubble is acting as a physical barrier preventing heliothis moths finding the cotton plants (Waters *et al;* 1998). Once the cotton plant emerged above the standing wheat stubble, there was no difference in chemical application for heliothis control between treatments. If this height structure phenomena is affecting the heliothis moth seeking out young cotton plants, results would be expected to vary between cotton growing areas depending on the amount and height of stubble retained from previous wheat crops. The rapid increase in the number of growers trialing wheat cotton rotations both in the EIA and in Southern cotton growing regions will greatly assist researchers in understanding this phenomena. Work is currently being carried out in Central Qld by DPI entomologists, will look at the interaction of crop height structures and heliothis moth behaviour.

Wheat-cotton double cropping and IPM – the China Experience

Whilst there have been limited reports of reduced heliothis pressure in W-C systems in Australia, in The Yellow River Valley of China W-C forms part of an integrated pest management system for the region (Xia 1994). Xia found that structures of insect communities and the incidence of major insect pests in W-C double cropping are quite different from those in single cotton cropping. In general a W-C system was found to be more diverse and more stable than single cotton cropping thus possessing less possibility for insect pest outbreaks. In addition, biodiversity of beneficials and stability in W-C double cropping were greater than in single cotton cropping and provide a basis for natural control.

Future Direction

Current management of cotton pests based on chemical insecticides is rapidly becoming no longer environmentally or economically viable. Early indications suggest that a W-C system is effective in reducing heliothis numbers and insecticide applications in high pressure seasons. However, further work is required to assess the effectiveness of the management system under the full range of seasonal conditions

Whilst the recent emphasis has been to reduce chemical applications in the farming system, growers should be aware of the proven benefits of cereal rotations on improving water quality, reduced erosion and improved soil condition (Waters *et al*; 1998) . This is particularly important at present where there is an increasing pressure for growers to gain accreditation through Best Management Practice.

Trap crops

Background

At the end of the 1996-97 season, cotton growers in the Emerald Irrigation Area (EIA) decided to trial a strategic beginning- and end-of-season (BEOS) trap-cropping program as a first step in the development of an area-wide management strategy for *Helicoverpa* spp (Sequeira 1998). Since its initial implementation, the Emerald program has generated considerable interest in alternative (non-chemical based) population management tactics throughout the Australian cotton industry. There has been renewed awareness of the need for integrated pest management in an environment characterised by high levels of insecticide resistance in pest populations. Several other growing areas within the Australian cotton belt have begun to move down the path of trap cropping and area-wide IPM programs.

Whilst the program has continued to enjoy a high level of support within the cotton growing community in central Queensland, there is a real need to evaluate the achievements of this research and its likely impact. In the following sections progress achieved at the end of three cycles of trap cropping in Emerald is summarised. Possible future development of the program is also outlined.

Evaluation of the Emerald trap-cropping program

Are the trap crops working?

Evaluation of the Emerald trap-cropping program is challenging for several reasons. The mobility of *Helicoverpa* spp. and the area-wide or regional scale of the Emerald trap-cropping program makes it difficult, if not impossible, to compare 'treatment' and 'control' areas. The design and objectives of the BEOS model of trap cropping (discussed in detail by Sequeira 1998) preclude traditional evaluation options such as % reduction in damage on the main crop used in other trap-crop strategies. The pest sink effect of the trap crop in relation to the main crop cannot be evaluated for the spring component of the program because the main crop is planted after the destruction of the trap crop. Traditional evaluation criteria are also inappropriate for determining the impact of the summer trap crop component because the objective of this component was not immediate reduction in damage to the main crop. Furthermore, the minuscule area of the trap crop in relation to the main crop limits its use as an in-season *Helicoverpa* sink.

In view of the strategic objectives of the trap cropping program (see Sequeira 1998 for details), its impact can be evaluated in one of several ways. These include the following: (a) Quantification of the long-term trend in pest pressure on the main crop (cotton) before and after the implementation of the program. (b) Quantification of the long-term trend in levels of resistance to commercial insecticides before and after the implementation of the program. (c) Evaluation of participation by growers and interest in adoption of IPM options. (d) Assessment of action learning opportunities provided by the program, and increased levels of communication between individuals and groups of growers.

As an example of (a) above, egg-laying activity on cotton during the first two months of the season as indicated by commercial cotton crop scouting data for five farms in the Emerald area over a period of 11 seasons is summarised in Fig. (1). If the spring trap crops (chickpea) had a significant impact on the population dynamics of Helicoverpa, this impact would be manifested as a reduction in early season pressure on cotton after the onset of the program. Fig. (1) shows that the lowest mean egg density for October was recorded in 1997, followed by 1999. The second highest mean egg density for October was recorded in 1998. A similar pattern emerges for the month of November.

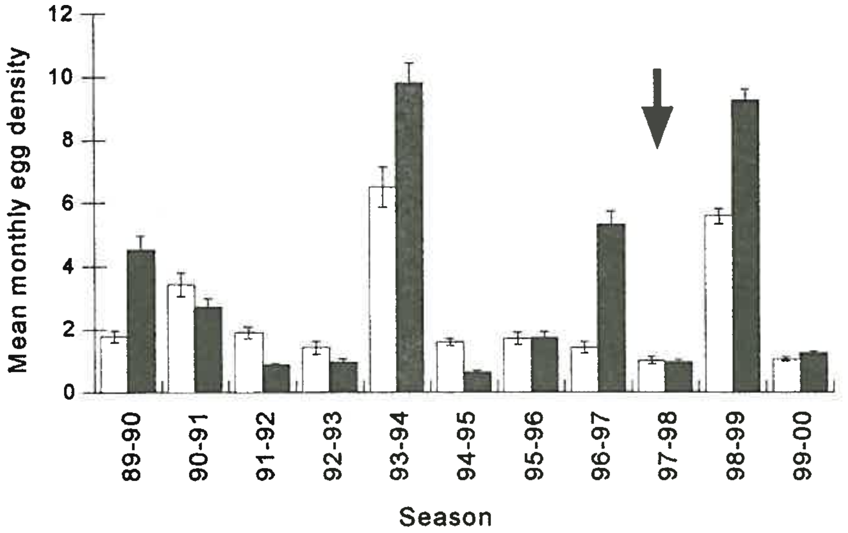


Fig. 1. Long-term Mean monthly egg density of cotton crops (average of five farms) for the months of October and November in the Emerald irrigation area. The arrow marks the first season of trap cropping.

The analysis of egg-laying activity (Fig. 1) shows that low *Helicoverpa* egg and larval density was observed in two of the three trap-cropping cycles (seasons) after the first implementation of the program at beginning of the 1997-98 season. High pressure on cotton throughout the 1998-99 season appears to be related to *Helicoverpa* activity resulting from an extended commercial chickpea cropping window in the winter of 1998 (discussed in the next section, below). A low-pressure start to the cotton season also occurred in several years prior to the introduction of the program. This leads to the conclusion that the direct impact of the spring trap-cropping component, in terms of a reduction in egg density on cotton early in the season, cannot be clearly distinguished from that of other weather related and external regulatory factors influencing *Helicoverpa* population dynamics. However, it must be recognised that the current data set based on three cycles of trap cropping may not be adequate for a definitive assessment of the impact of the trap-cropping program.

The potential impact of the summer trap crops (pigeon pea) on moth dynamics and resistance to insecticides was undermined largely by agronomic issues. Low viability of the pigeon pea seed and untimely rainfall resulted in poor plant stands and subsequent loss of most pigeon pea stands in year two (1998-99) of the program. Year three (1999-2000) revealed additional agronomic issues such as very early flowering and maturation of pigeon pea stands, thereby rendering the sink effect of the trap crops ineffective at the end of the cotton season. These agronomic problems cast doubts on the suitability of the pigeon pea cultivar(s) currently used for trap cropping. It follows that the likely impact of the summer trap-cropping component of the program will be assessable only after several cycles have been completed.

Despite our inability to demonstrate a clear and definite impact of the trap-cropping program, we have been able to show very clearly that chickpea crops planted in June/July can be used very successfully as sinks for *Helicoverpa* spp. in spring. Random drop-sheet sampling 10 x $1m^2$ areas of n=2 crops in 1997, n=6 crops in 1998 and n=4 crops in 1999 between July and September indicates population densities ranging from 5 to 30 larvae/m^2. Of some 63 individual farms or farming units in the EIA, at least 55 (87%) planted chickpea trap crops over the three-year period indicated in Fig. (3). The total area under chickpea trap crops during the period ranged from 120 to 140 hectares. Using a conservative mean of 10 larvae/m^2 over all three years, destruction of the trap crops in late August/early September potentially eliminated more than 12 million larvae each year prior to spring planting of cotton and other crops. A similar result was found for pigeon pea trap crops. Even in seasons where problems with seed quality and plant stand were encountered, crops that came up well successfully attracted egg lays at the end of the season.

What factors limit the impact of the trap-cropping program?

A major limitation of the Emerald program stems from its design. The Emerald crop production system is a complex one that facilitates *Helicoverpa* build up and movement (migration) amongst the various sources (cropping system components), within and between seasons. Fig. (2) shows the positioning of the trap crops in relation to the major *Helicoverpa* sources in system. The expected pattern of *Helicoverpa* movement (migration) between these sources is indicated by arrows. Broad acre chickpea and cotton are the primary sources of *Helicoverpa* in spring and mid-summer, respectively.

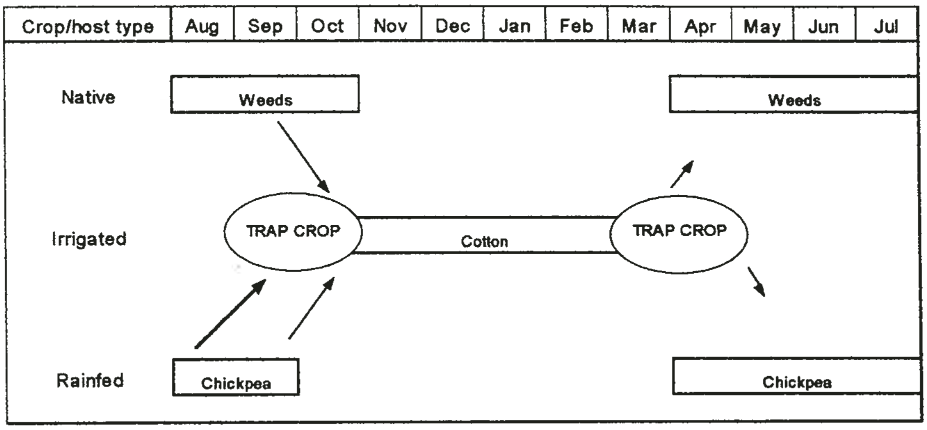


Fig. 2. Schematic diagram showing the major *Helicoverpa* producing sources in the Emerald crop production system. Also shown are the expected pattern of moth movement between components and positioning of trap crops. Details of the production system and population dynamics of *Helicoverpa* in relation to crops grown in the Emerald area can be found in Sequeira (1998) and Sequeira & Kelly (1999).

The success of the spring trap crops depends on their presence and attractiveness when *Helicoverpa* moths are emerging from diapause and/or commercial chickpea crops and/or weed hosts in the spring in search of new host plants such as cotton. Occasionally the presence of the trap crops and moth movement/migration is not synchronised, for example by an unusually long winter cropping season. When this occurs, the sink effect of the trap crops can be seriously undermined. This appears to have been the outcome in the spring of 1998/99 (see Fig. 1) and the resultant heavy Helicoverpa pressure on cotton throughout that season.

It is therefore clear that the winter crop component of the Emerald production system is a crucial factor in determining the pest status of *Helicoverpa* on late spring and summer crops. Thus, the potential early-season impact of the trap-cropping program on cotton crops in any given year will depend in part on the acreage under rain-fed chickpea and the degree of overlap with cotton. Many other factors influence trap crop performance and impact. Whilst these factors are for the most part poorly understood, those that influence the effectiveness of a spring trap crop are likely to be different from those that determine the impact of a summer trap crop.

One such factor is the relationship between height of the summer trap crop relative to adjacent cotton and its effectiveness as a population sink at the end of the season. The data at hand suggest that the trap crop needs to be substantially taller than the main crop to maximise the population sink effect. Another important factor is the ratio of the trap crop to the main crop.

In the trap-cropping literature this ratio appears to vary widely with the crop and target pest. This aspect of trap cropping remains a critical issue and may be best examined by means of computer simulation studies.

The picture emerging from the work so far is that in complex crop production systems, the current form of trap cropping may be of limited usefulness as a stand-alone pest management technique. The importance of winter crop refuges of *Helicoverpa* and their potential influence on the impact of the Emerald trap-cropping program suggests strongly that trap crops should be used within the framework of an area-wide management. Such a strategy would entail development of *Helicoverpa* population management options for rain-fed winter crops that could be enacted in conjunction with trap crops within irrigation areas. Summer or end-of-season trap crops may also be of limited usefulness in mixed-farming systems because of the presence of other commercial crops in the area that can compete for *Helicoverpa* eggs, thereby reducing the potential impact of the trap crops.

Future directions

The most common protocol for trap cropping is companion or strip cropping which involves planting a block or strip of the trap crop adjacent to the main crops to serve as a 'sink' for the pest population. One drawback of the current BEOS model of trap cropping is that each farm houses a single patch. If all the patches of trap crop are not planted at the same time or if some growers do not participate, this allows large proportions of the pest population to escape, thereby undermining the sink effect. Research is now in progress to examine the possibility of moving from a 'farm' scale (one patch of trap crop per farm) to a 'paddock' scale. The change in scale may be simply achieved by redistributing the current trap crop area (1%) as strips, one on every paddock of the farm. Other issues being considered are *Helicoverpa* management options for chickpea, tall varieties of pigeon pea and cotton, and alternative crop plants as trap crops.

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